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Evaluation of an Ultrasound-Guided Radial Artery Catheterization

Training Program for Nurse Anesthetists

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Abstract

Background: Arterial catheterization procedure is frequently performed by Certified Registered Nurse Anesthetists (CRNAs) in surgical suites. Ultrasound (US) guidance has emerged as a valuable adjunct for radial artery cannulation (RAC). There is a high level of evidence to support the use of US due to lower complications, reduced time to successful cannulation, and improved first attempt success. These advantages are highly dependent on the CRNA's knowledge of US technology along with experience and confidence. Despite the Anesthesia Patient Safety Foundation's recommendations that anesthesia providers should be competent in the use of advanced medical technologies, including ultrasonic imaging, to provide safe patient care, there is a lack of studies exploring implementation of a formal US training program within the nurse anesthesia literature. Lead CRNAs at a large Midwestern, academic hospital lacked formal US training to cannulate the radial artery with US guidance resulting in inconsistent use of US for arterial access. The purpose of this DNP project was to implement and explore the effects of a formal US training program on US knowledge, US competency, level of confidence in the use of US technology, and clinical utilization of US among Lead CRNAs.

Methods: This DNP project followed a quasi-experimental, one group, nonrandomized pre/post-test design. Prior to the implementation of an US educational intervention, Lead CRNAs were electronically sent a Needs Assessment and Pre-Intervention survey. Participants then completed an educational intervention, consisting of video, didactic, and hands on training. Utilizing a simulation US model, participants were provided with the opportunity to physically cannulate the model's radial artery with US technology. Immediately following the educational intervention, participants received a Post-Intervention survey. A 30-Day Follow-Up survey was electronically sent to participants thirty days after completing the US educational intervention. Data related to knowledge of US-related concepts, ability to perform US-related skills, competency, level of confidence and utilization was compiled over all three survey intervals.

Results: Data for this study was captured over three intervals: Needs Assessment/Pre-Intervention ($n = 45$), Post-Intervention ($n = 43$), and Thirty-Day Follow-up ($n = 39$). Planned post hoc contrasts confirmed that knowledge of US-related concepts, ability to perform US-related skills, competency, level of confidence and US utilization significantly increased between Pre-Intervention and Post-Educational Intervention ($p = .000$), between Pre-Intervention and 30-Day Follow-up ($p = .000$), but not between Post-Educational Intervention and 30-Day Follow-up ($p > .04$). Analysis of variance indicated that significant differences did not exist between the three survey periods for the ability to power the US machine on, indicating this skill was optimal prior to the educational intervention.

Conclusion: The findings from this DNP project demonstrated that implementation of an US educational program to guide RAC, that includes multiple learning strategies, can be implemented effectively to improving US knowledge, competence, level of confidence and utilization. In healthcare institutions where CRNAs have access to US technology, findings from this project provide supportive evidence for the development of an institutional program for establishing US competency to improve patient safety.

Evaluation of an Ultrasound-Guided Radial Artery Catheterization
Training Program for Nurse Anesthetists

Background

Arterial catheterization is frequently performed by anesthesia providers in the surgical suite, and is the gold standard for hemodynamic monitoring. The radial artery is the most common site (Miller A.G. et al., 2014). Due to its low rate of complications, superficial course and presence of alternate blood supply to the hand via the ulnar artery, the Centers for Disease Control and Prevention (CDC) recommends the radial artery as the first choice for arterial catheter placement (Ammar, Ali, & Furqan, 2017). The traditional method of cannulation involves locating the artery via pulse palpation and anatomical knowledge (Gao et al., 2015). In 30% of patients, however, the radial artery's origin and course are varied (Shiloh, Savel, Paulin, & Eisen, 2011). Insertion can be especially difficult in patients with hypotension, shock, abnormal clotting factors, obesity, atherosclerosis, or lack of a palpable pulse. Although generally considered to be a safe procedure, infectious, mechanical, and thromboembolic complications occur in 1% to 5% of cases (White, Halpin, Turner, & Wallace, 2016). Additionally, repeated attempts at cannulation often result in patient discomfort and suffering along with arterial spasm, thus worsening the cannulation success rate (Tang et al., 2014).

Due to its ability to reduce cannulation failure rates and associated morbidity, the use of direct vessel visualization with two-dimensional Ultrasound (US)-guidance for vascular access – including radial arterial line placement – has grown in popularity (Berk et al., 2013). US-imaging which involves the use of high frequency sound waves to transmit images (Moore & Copel, 2011) is a safe, effective, and efficient technology that allows for noninvasive visualization of a patient's anatomy. In the past two decades, technological advances have

resulted in US equipment not only being more compact, but also producing higher-quality imaging and being more affordable, thus increasing its point-of-care utilization to improve perioperative care (Moore & Copel, 2011). Point-of-care ultrasonography defined as, “ultrasonography brought to the patient and performed by the provider in real time”, can enhance procedural accuracy and reduce procedure-related complications (Moore & Copel, 2011). Utilization of US is well-validated and the standard of care for central venous cannulation and peripherally inserted central catheters (PICCs) (Gu, Tie, Liu, & Zeng, 2014; White et al., 2016). Current evidence suggests that US use for RAC should be the standard of care (Lamperti et al., 2012; Miller A.G. et al., 2014). The available body of research and practice literature has demonstrated improved first-pass success, improved mean-attempts to success, improved mean-time-to-success, and complication reduction in US-guided versus palpation method of RAC (Ammar et al., 2017; Hansen, Juhl-Olsen, Thorn, Frederiksen, & Sloth, 2014; Tang et al., 2014; Ueda, Bayman, Johnson, Odum, & Lee, 2015). A significant body of evidence supports the use of US as a best-practice adjunct to RAC (Troianos et al., 2011; White et al., 2016).

To actualize the clinical outcomes of US as documented in the literature, proper training is necessary. Without formal operator training, US may consume time and cause patient discomfort without benefits (American Institute of Ultrasound Medicine (AIUM), 2012). Formal training can reduce US-guided cannulation failure rates and ultimately improve the safety of patients undergoing the procedure (Troianos et al., 2011). Therefore, anesthesia providers who routinely place radial arterial catheters should be adequately educated in the use of US. When utilized by a qualified and trained anesthesia provider, there are no contraindications to US guidance as a procedural adjunct to RAC (Ailon, Mourad, Chien, Saun, & Dev, 2014b).

Statement of the Problem

Certified Registered Nurse Anesthetists (CRNAs) practicing at a large Midwestern, academic hospital lacked the necessary formal US training to cannulate the radial artery with the guidance of US. Due to varying levels of CRNA initial education and training, the use of US for vascular access is inconsistent among CRNAs; currently, the decision to utilize US is at the health care provider's discretion. Although CRNAs are encouraged to utilize US, a standardized US training program was not available. A needs assessment survey that was conducted earlier this year, indicated that 85% of the institution's CRNA's expressed a medium-to-high interest level in obtaining additional US training (Onsongo, 2017).

Project Purpose and Goals

The purpose of this DNP project was to develop and implement an educational intervention for the use of US to guide radial arterial line placement among Lead CRNAs in a large, Midwestern academic center. The goals of this project were to improve: (1) US knowledge, (2) US competency, and (3) the level of confidence in the use of US technology. By increasing these goals, clinical utilization of US to guide radial arterial cannulation (RAC) was hypothesized to increase.

Significance to the APRN and DNP

To deliver anesthesia services, the anesthesia department utilizes a care-team model that consists of anesthesiologists and CRNAs. Anesthesiologists, who receive thorough didactic and hands-on US training while in medical school and anesthesia residency, are well-versed in the placement of vascular lines (arterial and venous) with the guidance of US. Currently, the Council on Accreditation of Nurse Anesthesia Educational Programs (COA) accreditation standards for entry-level nurse anesthesia programs does not require US-guided technique training to obtain vascular access (Council on Accreditation (COA), 2017). For Student

Registered Nurse Anesthetists' (SRNAs), US-guided vascular access training is limited to point-of-care training and is highly variable in methodology and application.

This Midwestern academic institution currently employs 374 CRNAs who provide anesthesia services in a variety of settings. The high acuity of patients who seek medical care at this academic institution often present with poor vascular health, which results in a challenge to obtain vascular access. Although US guidance has been proven to be beneficial for radial arterial access and its use is within a CRNAs scope of practice, lack of a formal US training program has resulted in varying degrees of US utilization rates among CRNAs at this institution. The anesthesia medical staff of the institution has indicated a strong desire to have CRNAs competent and proficient in the use of US to guide vascular access, particularly radial arterial access. The institutional support, coupled with the patient safety implications of utilizing US technology for arterial access, provided the groundwork for this DNP project.

The American Association of Colleges of Nursing (AACN) utilizes eight essential domains that define the core to all advanced nursing practice roles (AACN, 2006). This project, utilizing a quality improvement framework, contributed to the advanced practice nursing role and was reflective of several DNP essentials. Success of this DNP project required an understanding of the science behind US technology (DNP Essential I). The population from which sample data were gathered for this project was limited to Lead CRNAs; however, the long-term goal of this project is to achieve US competency among all CRNAs within the anesthesia department (DNP Essential II). The role of the DNP is to demonstrate mastery in his/her specialization and to impart that knowledge to improve patient outcomes. Current literature provides evidence-based support for the use of US guidance for arterial access (DNP Essential III). The DNP prepared nurse is uniquely educated to provide leadership of the

implementation of technology into the clinical setting (DNP Essential IV). This project redefined the department standards for the use of US to guide arterial access amongst CRNAs. Success of this project required an interdisciplinary approach along with collaboration and support from leaders and stakeholders within the department (DNP Essential VI). CRNAs who are now educated in the use of US to guide radial arterial access have an alternative to the traditional palpation technique in patients who present with difficult access (DNP Essential VII). Overall, this project improved patient outcomes by increasing the frequency and types of procedures in which CRNAs use US (DNP Essential VIII).

Theoretical Foundation

The purpose of this DNP project was to develop an US educational intervention to increase CRNA's US knowledge, US competence, level of confidence in the use of US and therefore, utilization rate of US technology to guide RAC at a large academic medical center in the Midwest. The process of implementing an US educational intervention into the clinical setting was facilitated using an adult learning theoretical framework. Adult learning theory, or andragogy, was applicable to this project and was used to frame the overall structure and process of implementing this project. In the 1970s and 1980s, Malcolm Knowles conceived and developed the concept of andragogy to quantify his theories and practices of adult learning, and is based upon five assumptions. (Knowles, 1988). (Appendix A).

Concept of the Learner

As people mature into adulthood, they have a psychological need to be increasingly self-directed and independent, so teachers need to create an environment where adults can develop their latent, self-directed learning skills (Knowles, 1988).

Role of the Learners' Experiences

Adults attach more meaning to learning that they gain from experience rather than those that they acquire passively. Uncovering their experiences through experiential techniques (discussions, simulations, problem-solving activities, or case methods) is beneficial (Knowles, 1988).

Readiness to Learn

Adults are more amenable to learning a new skill when stated learning is oriented to the developmental tasks of their social or real-life, work-related roles. To be effective, then, training-for-learning must focus on the present and be related to the learner's current situation (Knowles, 1988).

Orientation to Learning

Adult learner's perspective changes from one of postponed application of knowledge to immediate application. Learning experiences should be organized around competency-development categories for immediate application (Knowles, 1988).

Motivation

Although some learning motivators come from external sources, the most effective motivators are internal (desire for increased job satisfaction, self-esteem). Teachers can enhance adult learner's motivation by incorporating the adult learning principles (Knowles, 1988). When adults participate in a positive learning experience that follows the five assumptions of andragogy, they are more likely to retain what they have learned and to apply it in their work

environment. Knowles also defined the Conditions of Learning and Principles of Teaching as they relate to Andragogy (Appendix A). These concepts guided the development of this educational intervention so that it was maximally effective towards the CRNA adult learners.

Definition of Terminology

The following theoretical terms and definitions were used for this DNP Project:

1. Lead CRNAs are designated CRNAs whose responsibilities include organizing surgical cases and room assignments along with supporting and carrying out practice leadership decisions. Additionally, Lead CRNA's act as a resource for in-room providers by assisting them with patient care activities and influencing them to perform at a high level.
2. Ultrasound is an imaging method that uses high-frequency sound waves to produce images of structures within the human body (Moore & Copel, 2011). For this DNP project, US was utilized to indirectly visualize the radial artery.
3. Competence is the ability to do something successfully or efficiently. For this DNP project, competence is having suitable or sufficient skill, knowledge, and experience for using US imaging technology to cannulate the radial artery (Competence, 2017).
4. Confidence is a feeling of self-assurance arising from one's appreciation of one's own ability to use US imaging technology to cannulate the radial artery (Confidence, 2017).
5. Utilization is the act of making practical and efficient use of US imaging technology in clinical practice (Utilization, 2017).

Clinical Question

The primary quality improvement question that guided this DNP project was: What are the effects of an US educational intervention on US knowledge, US competence, level of confidence in the use of US, and utilization of US technology in practice to guide RAC among practicing Lead CRNAs?

Literature Review

Databases queried to examine existing literature included PubMed, CINAHL, Ovid, EBSCO MegaFILE, Scopus, and Google Scholar. Keywords used in the database search included: CRNA, nurse anesthetist, APRN, provider, professional, physician, resident, anesthetic*, ultrasound*, arterial w/3 line* or catheter* or cannula*, placement, radial artery, staff training, train, staff development, teach, learn, educate*, instruct, class*, course, program, inservice, elearn, online, experiential, learn by doing, didactic, hands on, module, tutorial, class, program, video, simulation, competence*, proficiencies*. The keywords were grouped using the Boolean term “and” along with “or”. The search was narrowed by including articles available in English and limited to the last seven years. Articles were included if they focused on use of US to guide vascular placement, either arterial or venous, by trained providers. The primary search was for training of nurse anesthetists in the use of US; however, the body of relevant nurse anesthesia literature is relatively small, so the search was expanded to include physicians, APRNs and resident physicians. Finally, high-quality articles that met inclusion criteria for this project were critically reviewed. One hundred twenty-eight articles met the inclusion criteria and 33 articles were reviewed and used to synthesize the literature and develop an US-guided RAC training program for nurse anesthetists.

US-Guided Radial Arterial Access

The use of US to guide arterial line placement is well documented in the literature; its use has been shown to be beneficial for RAC and can be utilized effectively by CRNAs (American Association of Nurse Anesthetists, 2013b). Studies on US-guided cannulation of the radial artery suggest that the process may be easier and more efficient than standard landmark and palpation techniques (Lamperti et al., 2012). Difficulty obtaining arterial access by traditional palpation technique results in multiple attempts by a variety of providers. This is not only associated with delays in patient care, but also increased patient discomfort, costs, and provider frustration (Ailon, Mourad, Chien, Saun, & Dev, 2014a; Shiloh et al., 2011). Common primary and secondary clinical outcomes reviewed in the literature when comparing traditional palpation technique versus US-guided technique for RAC include: number of attempts, time to successful cannulation and associated complications (Ammar et al., 2017; Gao et al., 2015; Hansen et al., 2014; Seto et al., 2015; White et al., 2016).

Improved first-attempt success rates

Numerous systematic reviews and meta-analyses have indicated a clear benefit from US-guidance for RAC as evidenced by increased first-attempt success rates along with fewer mean-attempts to achieve successful cannulation. In a meta-analysis of eleven randomized controlled trials (RCTs), a high level of evidence for first-attempt success rate for cannulation was identified: US guidance improved first-attempt success rates by 14% to 37%, which increased overall success rates in the US-guided technique group by as much as 95%. A high level of evidence was found to support US's ability to reduce overall number of attempts (White et al., 2016). In a meta-analysis by Gao et al. (2015) eleven RCT's were selected. Statistically significant results were associated with a 47% increase in first-attempt success in both adult and pediatric patients in the US-guidance groups. Systematic reviews by both Gu, Tie, Liu and,

Zeng (2014) and Tang, et al. (2014) found similar results. Compared with palpation technique, US-guidance significantly increased first-attempt success and decreased mean number of attempts to successful catheter placement. In another meta-analysis and systematic review by Shiloh, Savel, Paulin, and Eisen (2011), pooled evidence demonstrated that US-guided RAC was associated with a 71% improvement in the likelihood of first-attempt success rates when compared to the palpation method. In a recent RCT, first-attempt success was achieved in 88% of patients in the US-guided group compared to 70% in the blind palpation group. Additionally, fewer attempts (an average of 1.16 attempts versus an average of 1.44 attempts) were seen overall in the US-guided group (Ammar et al., 2017). These results are comparable to an RCT by Hansen, Juhl-Olsen, Thorn, Frederiksen, and Sloth (2014) in which 40 subjects achieved 95% first-attempt success rates in the US versus 57.5% in the traditional palpation group. This latter group experienced a higher number of skin perforations from increased attempts at targeting the vessel and a significantly higher number of catheters used. Seto et al. (2015) also demonstrated improved first-pass success rate (64.8% versus 43.9%) and significant reduction in mean attempts in the US group compared to the palpation group (1.65 attempts versus 3.05 attempts). Due to strong evidence for arterial catheterization first-pass success with US, an expert panel from the International Liaison Committee on Ultrasound Vascular Access (ILC-USVA) strongly recommended that it be routinely utilized in adults (Troianos et al., 2011).

Decreased time to cannulation and complications

Regarding the secondary outcomes of time to achieve successful cannulation and associated vascular complications, reduced mean-time to successful cannulation along with fewer complications have been demonstrated in groups randomized to US-guidance. Not only does US guidance reduce time to cannulation, but also results in higher success rates (Ailon et

al., 2014a). In a well-organized study, 698 patients requiring RAC were randomized to either traditional palpation method (351) or to real-time US guidance (347). Patients randomized to the US group had shorter time required for arterial line placement (88 seconds versus 108 seconds). Ten patients in the palpation group required crossover to US guidance following five minutes of unsuccessful attempts, with US successfully rescuing eight of the ten cases. In difficult procedures, defined as those requiring five or more minutes, US guidance reduced the number of difficult procedures from 6.8% to 3.7% (Seto et al., 2015). A different RCT also demonstrated reduced arterial line insertion time. Patients randomized to the US-guided group obtained first-attempt access in 77.68 seconds compared to 95.46 seconds in the palpation group, an 18.6% improvement (Ammar et al., 2017). Recent systematic reviews and meta-analysis similarly found reductions in mean time to successful cannulation in those randomized to US guidance (Gu et al., 2014; Tang et al., 2014; White et al., 2016). These systematic reviews also indicated a lower incidence of complications such as hematoma formation in patients who undergo US guidance for RAC. This is presumably related to the reduction in the number of attempts (Gu et al., 2014; Shiloh & Eisen, 2010; Shiloh et al., 2011; Tang et al., 2014).

Formal US Training

The improved safety and outcomes attained with US is dependent on adequate training and experience and therefore is highly operator-dependent (Moore, 2014). Formal training to improve patient safety and realize clinical outcomes is supported by the literature (Troianos et al., 2011). Practitioners who utilize US without training have been shown to have more complications and decreased success rates (Falyar, 2010); therefore, proper training and familiarization with US-guided technique is necessary for inexperienced operators prior to applying it to RAC (Tang et al., 2014). The Anesthesia Patient Safety Foundation (APSF)

believes anesthesia professionals should become competent in the use of US by participating in an education program that not only includes training, but also assesses and documents competency (APSF, 2011). The American Association of Nurse Anesthetists (AANA) *Scope and Standards for Nurse Anesthesia Practice* endorses the use of US to improve patient safety and outcomes, with individual competency achieved through educational offerings and individual clinical experience (American Association of Nurse Anesthetists, 2013a).

Unfortunately, the amount and type of education and training along with a specific number of procedures required to be deemed competent is lacking in the scientific literature (Troianos et al., 2011). This is due to the lack of homogeneity in the providers executing these procedures, with Physicians, Respiratory Therapists, and Advanced Practice Registered Nurses who are all documented in the literature as utilizing US technique to guide vascular access (Miller A.G. & Bardin, 2016). The amount of training to obtain competency and the frequency at which providers utilize US to guide vascular access varies among individual professionals.

Additionally, practitioners acquire knowledge and develop dexterity in the use of US at different rates (Tang et al., 2014), so delineating a specific number of supervised US-guided placements for independent practice is not a sufficient method to measure competency (Todsén et al., 2015).

A recent consensus statement by the American Institute of Ultrasound Medicine (AIUM) does not delineate a specific number of supervised US-guided procedures to deem a practitioner competent; however, it does suggest that advanced training and education is required (Moore, 2014). Recently published guidelines by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists recommend a minimum of ten vascular access procedures, under the supervision of an experienced practitioner, as necessary to demonstrate competence and therefore practice the technique independently (Troianos et al., 2011).

Despite scientific literature that supports US-guidance for RAC, the primary issue preventing its widespread use is that it requires advanced training and education, with the primary source of US training occurring on-site at the point-of-care (Moore & Copel, 2011; Tolsgaard et al., 2014). Unfortunately, the literature lacks competency-based education and standardized training, evidenced by great variability in education among different specialties (Lewiss, Hoffmann, Beaulieu, & Phelan, 2014). The Agency for Healthcare Research and Quality (AHRQ) set forth recommended training objectives for US-guided vascular cannulation. These objectives included both cognitive and technical skills in determining competence for independent practice (Troianos et al., 2011) (Appendix B). To be skilled in the use of point-of-care US, proficiency in three areas has been suggested which include: image acquisition, image interpretation, and ability to integrate that interpretation into practice (Lewiss et al., 2014).

Learning methodologies

For clinicians to develop competency in US, a variety of learning methodologies should be considered to enhance variability in learning styles among providers. Blended learning models that include a combination of classroom didactic and simulation are supported by the literature for attaining US proficiency (Lewiss et al., 2014). When applied to US training, simulation is a reliable method for measuring procedural competency; additionally, it provides a stress-reduced environment for training (Lewiss et al., 2014). Gasko et al. (2012) found that multiple learning strategies, including didactic and simulation are more effective than either of the two methods alone in educating student registered nurse anesthetists on the use of US to guide regional anesthesia techniques. A prospective study of nurse anesthetists was undertaken to evaluate the effect of implementing an US-guided training program for the placement of peripheral venous catheters (PVCs) in patients with difficult intravenous access (DIVA). The

program included multiple learning strategies including classroom lectures, practical demonstration, and simulation on gelatin phantoms. A high rate of successful cannulation was demonstrated (0% pre-training to 83% post-training) along with reduced procedure time (from 20 minutes to 10 minutes) and reduced median number of attempts (from 3 attempts to 2 attempts) (Partovi-Deilami, Nielsen, Moller, Nesheim, & Jorgensen, 2016). In another prospective observational study, an experiential education model was utilized to educate preclinical medical students in basic US skills. The model consisted of didactic presentations, hands-on practice, and supervised real-time US examination with image interpretation. Statistically significant pretest to posttest results indicated that education in both the classroom and clinical environment is an effective way to teach basic US skills (Shokoohi et al., 2016).

National support for US-guidance

Several national societies and organizations have endorsed the use of US guidance for vascular procedures. The American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists recommend the use of US for RAC with Category A, Level 1 evidence to improve first-pass success (Troianos et al., 2011). In 2012, the American Institute of Ultrasound in Medicine (AIUM) collaborated with a variety of medical and nursing organizations, including the American Society of Anesthesiologists (ASA) and the American Association of Nurse Anesthetists (AANA) to develop practice guidelines recommending US guidance during arterial cannulation (American Institute of Ultrasound Medicine (AIUM), 2012). In 2012, a panel of international US-guided cannulation experts convened in Amsterdam at the World Conference on Vascular Access. Their consensus recommendation was for routine use of US for RAC in adults when trained operators are available (Lamperti et al., 2012). The Anesthesia Patient Safety Foundation (APSF) believes all anesthesia providers should be

competent in the use of advanced medical technologies, including ultrasonic imaging, to provide safe patient care (Anesthesia Patient Safety Foundation (APSF), 2011).

Research Limitations

Although reviews of the current literature provide evidence-based support for the use of US to guide RAC, several limitations exist such as the considerable amount of heterogeneity and variability with respect to population characteristics, US equipment, operator training, and operator experience. Due to a lack of sufficient information provided in some of the studies – and thus not knowing if patients and operators in the control versus intervention groups were similar – results may potentially be biased (Shiloh et al., 2011; White et al., 2016). There is a lack of high quality RCTs recommending the use of US as a routine, best-practice for standard of care in RAC; rather, available literature recommends US use as a best-practice adjunct in patients who present with difficult access (Gu et al. 2014; Troianos et al. 2011).

Methodology

Description of Study Population

For this DNP project, the effects of a new US educational intervention upon knowledge, competence, level of confidence and utilization of US to guide RAC among English speaking, Lead CRNAs practicing at a large Midwestern, academic hospital was evaluated. A convenience sample of forty-seven Lead CRNAs within the Cardiac, Neurosurgery, Pediatrics, Multi, Central, Vascular Lab, Cardiac Catheter Lab and GI divisions were selected to participate in this project. Non-Lead CRNAs in these areas were excluded along with the Primary Investigator.

Lead CRNAs were specifically selected because of the role that they serve in relation to other anesthesia providers in the institution. Lead CRNAs function as an expert resource to in-room providers and are often called upon to assist with arterial cannulation when the most

frequent method of RAC, palpation method, is unsuccessful. With formal training in the use of US technology, Lead CRNAs would be able to offer in-room providers an advanced, alternative method of RAC. The benefits of US for RAC is well-documented in the literature; however, US use is highly user dependent and these documented benefits are reliant on an anesthesia provider's knowledge of US technology along with experience and confidence (Gao et al., 2015; Seto et al., 2015; White et al., 2016). Lead CRNAs are well-positioned to influence other anesthesia providers by serving as role models in the use of US technology. Most of the Lead CRNAs either have attained their DNP or are currently enrolled in a DNP program. Their DNP education uniquely has prepared them to implement evidence-based quality improvement projects to improve the quality and safety of patient care.

Study Design

A quasi-experimental, one group, nonrandomized pre/post-test project was conducted at this large, academic medical center in the Midwest. Prior to the educational intervention, both a Needs Assessment Survey and a Pre-Intervention Survey were completed to assist with content development. Immediately following the educational intervention and thirty-days after the educational intervention, follow-up surveys were administered. The methodology of this project followed the systematic approach of the Plan-Do-Study-Act (PDSA) model, which is frequently used in healthcare to facilitate quality improvement projects by implementing change, solving problems, and continuously improving processes. Moreover, the PDSA model is a scientific method that can be used for action-orientated learning (Minnesota Department of Health, 2017).

Among Lead CRNAs, increases in US knowledge, competency, and level of confidence was accomplished through a variety of broad-based educational strategies. This included exposure to video, didactic, and hands-on simulation. Content for the didactic and hands-on

simulation incorporated the Agency for Healthcare Research and Quality (AHRQ) recommended training objectives for US-guided vascular cannulation that include both cognitive and technical skills to determine competence for independent practice (Troianos et al., 2011) (Appendix B).

Organizational Analysis

The anesthesia department utilizes a care-team model that consists of Anesthesiologists and CRNAs in the delivery of anesthesia services. Although placement of a radial arterial line with US-guidance is within a CRNA's scope of practice, lack of formal training has resulted in anesthesiologists, who receive formal US training, placing most of radial arterial lines that require US-guidance. Prior to its inception, support for this DNP project was overwhelmingly received from the Anesthesia Clinical Practice Committee, which consists of both anesthesiologists and CRNAs.

Study Procedure

An educational intervention was presented on multiple dates in January and February 2018 to groups of four to six participants at a time. An institutional video, created by the Respiratory Therapy department, was used to demonstrate the use of US to guide RAC. The didactic portion of the intervention consisted of a fifteen-minute PowerPoint presentation that incorporated seven key elements including: Fundamentals of US technology, US equipment operation, sterile technique, image optimization, systematic examination, image interpretation and documentation of examination (Appendix C). The last portion of the educational program included an educational exercise where subjects performed a noninvasive, US-guided radial artery assessment on each other in both the short-axis (out-of-plane) and long-axis (in-plane) views. To provide a concluding exercise with respect to the utilization of an US model, participants in the study were provided the opportunity to cannulate a simulation model's radial

artery with US guidance. Appendix D provides a detailed timeline for the implementation of this DNP project.

Survey Description

US Educational Intervention: Needs Assessment/Pre-Intervention Survey. On December 5, 2017, the Needs Assessment/Pre-Intervention Survey was electronically sent to participants via REDCap secure web application. The first part of the survey, the Needs Assessment Survey, included questions regarding previous patient encounters with difficult arterial access, US utilization in the previous six months to guide RAC, and type of education received, either formal or informal, on US imaging. Using a five-point Likert scale, participant's level of agreement with the following two statements was measured: "Being proficient in the use of US to guide RAC will enhance the CRNA practice in my institution" and "I have the training and experience needed to perform US-guided RAC independently". The last question asked participants to indicate their level of interest in receiving formal US education and hands on training for RAC on a five-point Likert scale (Appendix E).

The second part of this Pre-Intervention Survey included demographic-type questions on gender, age, highest level of education (certificate, bachelor's, master's, doctorate), years practicing as a CRNA, and years as a Lead CRNA. Four questions asked participants to indicate their understanding of US-related concepts on a four-point Likert scale. Participants were then asked to rate their ability to perform twelve, US-related skills on a four-point Likert scale. Utilizing a Yes/No question, participants were asked about their ability to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for US-guided RAC. Baseline level of confidence in the use of US to guide RAC and

perceived competency in the use of US to guide RAC were measured utilizing a five-point Likert scale. (Appendix E)

US Educational Intervention: Post-Intervention Survey. Beginning January 15, 2018, nine US educational interventions were offered. Following each intervention, a Post-Intervention Survey was electronically sent to participants via REDCap secure web application. Participants were given two weeks to complete the survey. Utilizing the same questions from the Pre-Intervention survey, participants were again asked to indicate their understanding of four US-related concepts and twelve US related skills on a four-point Likert scale. Participants were again asked about their ability to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for US-guided RAC. Post-educational level of confidence in the use of US to guide RAC and perceived competency in the use of US to guide RAC were measured utilizing a Five-point Likert scale. Utilization was measured by asking participants how likely they were to utilize US technology to guide RAC because of the education intervention. Part of the educational intervention involved utilizing US to cannulate a simulation mannequin's radial artery. Successful cannulation of the model's radial artery with the guidance of US was measured utilizing a Yes or No question. Lastly, participants were asked to select the portion of the educational intervention that was most conducive to their learning needs (video, PowerPoint, or simulation with US model) (Appendix E).

US Educational Intervention: 30-Day Post-Intervention Survey. Thirty days after attending one of the nine assigned US education interventions, participants were electronically sent the 30-day Post-Intervention Survey via REDCap secure web application. Participants were given two weeks to complete the survey. Utilizing the same questions from the Pre- and Post-

Intervention surveys, participants were again asked to indicate their understanding of four US-related concepts and twelve US related skills on a four-point Likert scale. Participants were again asked about their ability to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for US-guided RAC. The thirty-day, post-educational level-of-confidence in the use of US to guide RAC and perceived competency in the use of US to guide RAC was measured utilizing a Five-point Likert scale. Utilization was measured by asking participants how many times that they utilized US to guide RAC in the thirty days since they received US education. Participants who indicated that they had not utilized US in the past thirty days were then presented with an additional question asking them to cite a reason for not using the technology (Appendix E).

Protection of Human Subjects

This project was classified as a quality improvement project by both the University of North Dakota Institutional Review Board and institution IRB prior to data collection, so it was granted exempt status. Prior to attending the educational program, Lead CRNAs received a cover letter that provided information about the DNP project and invited them to voluntarily participate. The cover letter included the purpose of the project, provided researcher's contact information, stated assurance of respondent confidentiality through collection of de-identified data, and detailed components of consent (Appendix G). The participants were informed that completing the Needs Assessment Survey and Pre-Intervention Survey, respectively, constituted consent to participate in the project. All data obtained from this study were de-identified and reported in aggregate format. Confidentiality was maintained by means of collecting aggregate data via REDCap secure web application. Participation in this DNP project posed minimal risk to participants.

Projected Outcomes

1. US Knowledge
 - a. By May 1, 2018, at least 50% of Lead CRNAs who participated in the educational intervention will rate their understanding of US-related concepts as “understand most of it” and “understand very well” on a four-point Likert scale as measured by comparing aggregate scores of four US-related concepts on the Pre-Intervention Survey to aggregate scores on the Post Intervention and 30-day Follow-Up Surveys.
 - b. By May 1, 2018, at least 50% of Lead CRNAs who participated in the educational intervention will rate their ability to perform US-related skills as “Independent-confident, proficient, do not need supportive cues” on a four-point Likert scale, as measured by comparing aggregate scores of twelve, US-related skills on the Pre-Intervention Survey to aggregate scores on the Post-Intervention and 30-day Follow-Up Surveys.
2. US Competency
 1. By May 1, 2018, at least 80% of Lead CRNAs who participated in the educational intervention will successfully cannulate an US trainer model’s radial artery with US-guidance as evidenced by return of red liquid in the catheter, and indirect visualization of the catheter in the artery via US.
 2. By May 1, 2018, the perceived competency among Lead CRNAs who participated in the educational intervention will increase as evidenced by aggregate improvements in self-reported five-point Likert scale competency ratings from the Pre-Intervention to the Post-Intervention and 30-day Follow-up Surveys.

3. Level of Confidence

- a. By May 1, 2018, the level of confidence in the use of US technology to guide RAC among Lead CRNAs who participated in the educational intervention will increase as evidenced by aggregate improvements in self-reported five-point Likert scale level of confidence ratings from the Pre-Intervention to the Post-Intervention and 30-day Follow-up Surveys.

4. US Utilization

- a. By May 1, 2018, at least 50% of Lead CRNAs who participated in the educational intervention will indicate usage of US to guide RAC in their clinical practice as measured by participant response on the 30-day Follow-up survey to the question, “In the last 30 days, how many times have you utilized US to guide RAC in your clinical practice?”

Data Analysis

The primary variable of this project was US utilization; secondary variables included US knowledge, US competency, and level of confidence in using US technology. The implementation of an US educational intervention was hypothesized to improve the secondary variables such that the primary variable, US utilization to guide RAC, would be increased.

Self-reported knowledge was measured by comparing participant’s understanding of US-related concepts on a four-point Likert scale that ranged from “Understand very well” to “Do not understand”, along with participant’s ability to perform US-related skills on a four-point Likert scale that ranged from independent-confident, proficient, do not need supportive cues to dependent-fully dependent on assistance to execute this task from the Pre-Intervention Survey to the Post-Intervention and 30-Day Follow-Up Surveys. Self-reported US competency using US

technology was measured by comparing Pre-Intervention, Post-Intervention, and 30-Day Follow-up Survey responses with a five-point Likert scale ranging from highly competent to not competent. Additionally, the Post-Intervention Survey recorded participant's ability to successfully cannulate the model's radial artery with US guidance, as evidenced by the return of red liquid in the catheter and indirect visualization of the catheter in the artery via US.

Likewise, level of confidence in the use of US technology to guide RAC was measured by comparing Pre-Intervention, Post-Intervention, and 30-Day Follow-up Survey responses on a five-point Likert scale ranging from very confident to not at all confident. Lastly, US utilization was measured by comparing past utilization of US on the Needs Assessment Survey to current utilization thirty days following participation in the educational intervention. Likelihood of US utilization in the participant's clinical practice was also measured in the Post-Intervention Survey with a five-point Likert scale ranging from extremely likely to extremely unlikely.

Results

The purpose of this quality improvement project was to develop and implement an educational intervention for the use of US to guide RAC among Lead CRNAs in a large, Midwestern academic center. The goal of this project was to determine the effects of this US educational intervention on US knowledge, US competence, level of confidence in the use of US and utilization of US technology in practice to guide RAC among Lead CRNAs. Utilizing a quasi-experimental, pretest/posttest design, data were collected via RedCap secure web application and analyzed using Statistical Package for the Social Sciences (SPSS). RedCap was only available to utilize for participant survey completion while on the institution's network; due to travel and personal reasons, three participants were unable to complete all three surveys. Results of the data analysis follow.

Data were captured over three time-periods: Needs Assessment/Pre-Intervention ($n = 45$), Post-Intervention ($n = 43$), and 30-Day Follow-up ($n = 39$). Demographics for the Pre-Intervention group consisted of thirty-nine (86.7%) health-care providers who identified as having a master's degree, and six (13.3%) as having a doctor's degree; with respect to age-group, twenty-five (55.6%) identified as 35 to 44 years-of-age, eight (17.7%) identified as 25 to 34 years-of-age, nine (20%) identified as 45 to 54 years-of-age, and three (6.7%) identified as age 55 and over. Thirty-nine (86.7%) of respondents reported as having received anesthesia training at this mid-western medical center, and six (13.3%) reported as having received anesthesia training at other institutions. With respect to years practicing as a CRNA, nineteen (42.2%) reported 5 to 10 years of clinical practice, fourteen (31%) reported less than 5 years, nine (20.0%) reported 11 to 15 years, two (4.4%) reported 16 to 20 years while one (2.2%) reported more than 20 years. Years practicing as a Lead CRNA were also gathered. Thirty-nine (86.6%) reported less than 5 years; five (11.1%) reported 5 to 10 years and one (2.2%) reported 11 to 15 years.

An eight question Needs Assessment survey was included with the Pre-Intervention survey. Data from the Needs Assessment revealed that 95.6% of respondents reported encountering at least one patient per month with difficult arterial access. Use of US to guide RAC is considered a "rescue" technique when the traditional palpation technique fails. Most respondents, 86.7%, indicated that they ask for help following 2-3 failed traditional attempts. When US is indicated, the covering anesthesiologist typically performs the procedure due to CRNA lack of training and experience; 65.1% of respondents indicated that they had not received education, either formal or informal, on US-guided RAC. For those participants who did receive training, clinically-based training by a colleague (24.4%) was the likeliest form. Two

questions asked respondents to indicate their level of agreement. For the question regarding having the training and experience needed to perform US-guided RAC independently, 46.7% either disagreed or strongly disagreed. A total of 88.9% either agreed or strongly agreed that being proficient in the use of US to guide RAC will enhance the institution's CRNA practice. Participant's level of interest in a formal US training program for RAC indicated that 93.4% were somewhat interested to very interested.

Over the three time-periods for which US concept and skills data were gathered, eighteen questions had Likert-type responses which permitted cross-sectional statistical comparisons via ANOVA and concomitant post hoc tests where an ANOVA was statistically significant. The means, standard deviations and *p*-values are presented in Appendix F.

Understanding of CDC recommended barrier precautions for arterial placement was formatted as a "Yes/No" question, "Are you able to verbalize the Centers for Disease Control and Prevention's recommendation barrier precautions related to sterile techniques for US-guided, RAC?" In the Pre-Intervention period, 33.33% of respondents answered "Yes," while 93.02% answered "Yes" for the Post-Intervention period and 89.74% of respondents answered "Yes" for the 30-Day Follow-up period.

For the 30-Day Follow-Up question, "In the last 30 days, how many times have you utilized US to guide RAC in your clinical practice?", 33.3% respondents indicated zero times; 33.3% indicated one time; 17.9% indicated two times; 5.1% indicated three times; 2.5% indicated five times; 7.7% indicated more than five times.

Discussion of Findings

The results of this study demonstrate that CRNAs can perform US-guided RAC following completion of a training program. Similar results were seen in studies implementing

RAC training programs for other specialties including Respiratory Therapists and Intensive Care Nurses (Chee et al., 2010; Miller A.G. & Bardin, 2016). Results from the study's Needs Assessment revealed that participants encountered patients monthly with difficult arterial access (95.6%), and that 65.1% of participants received either formal or informal US training, with clinically-based training by a colleague being the most likely source (24.4%). A high level of interest in a formal US training program for RAC (93.4%) along with agreement that being proficient in the use of US to guide RAC will enhance the institution's CRNA practice provided necessary stakeholder buy-in to implement this educational intervention for RAC. The implementation of this DNP project was beneficial since it enhanced CRNAs' US knowledge, US competence, level of confidence in the use of US and utilization of US technology in practice to guide RAC.

Findings Related to US Knowledge.

By May 1, 2018, at least 50% of Lead CRNAs who participate in the educational intervention will rate their understanding of US-related concepts as “understand most of it” and “understand very well” on a four-point Likert scale as measured by comparing aggregate scores of four US-related concepts on the Pre-Intervention Survey to aggregate scores on the Post Intervention and 30-day Follow-Up Surveys, as well.

Knowledge of four US-related concepts were compared utilizing a four-point knowledge Likert scale (do not understand, understand a little, understand most of it, or understand very well).

- A total of 40% of participants in the Pre-Intervention survey indicated understanding (most of it or very well) of the concept: Understanding how US transmits sound waves

into a resultant image. This percentage increased to 88.4% in the Post-Intervention survey but slightly decreased to 84.6% in the 30-day Follow Up survey.

- A total of 37.7% of participants in the Pre-Intervention survey indicated understanding (most of it or very well) of the concept: Understanding of how penetration affects US images. This percentage increased to 93.1% in the Post-Intervention survey but decreased to 84.6% in the 30-day Follow Up survey.
- A total of 26.6% of participants in the Pre-Intervention survey indicated understanding (most of it or very well) of the concept: Understanding of how resolution affects US images. This percentage increased to 90.7% in the Post-Intervention survey but decreased to 84.6% in the 30-day Follow Up survey.
- A total of 24.4% of participants in the Pre-Intervention survey indicated understanding (most of it or very well) of the concept: Understanding of how echogenicity affects US images. This percentage increased to 88.3% in the Post-Intervention survey but slightly decreased to 82% in the 30-day Follow Up survey.

Planned, post hoc contrasts revealed that understanding significantly increased for all four US-related concepts between Pre-Intervention and Post-Intervention, between Pre-Intervention and 30-Day Follow-up, but not between Post-Intervention and 30-Day Follow-up. Lack of changes in the Post-Intervention and 30-Day Follow Up may be related to the fact that knowledge acquired in the educational intervention had not changed in the thirty days immediately following it.

Findings Related to the Performance of US

By May 1, 2018, at least 50% of Lead CRNAs who participate in the educational intervention will rate their ability to perform US-related skills as “Independent-confident,

proficient, do not need supportive cues” on a four-point Likert scale, as measured by comparing aggregate scores of 12 US-related skills on the Pre-Intervention Survey to aggregate scores on the Post-Intervention and 30-day Follow-Up Surveys, as well.

The ability to perform twelve US-related skills were compared utilizing a four-point Likert scale (Dependent-fully dependent on assistance to complete this task to Independent-confident, proficient, do not need supportive cues).

- A total of 73.3% of participants in the Pre-Intervention survey indicated that they were independent in their ability to turn on the US machine. This percentage increased to 95.3% in the Post-Intervention survey but decreased to 87.2% in the 30-day Follow Up survey.
- A total of 24.4% of participants in the Pre-Intervention survey indicated that they were independent in their ability to select an appropriate US probe. This percentage increased to 86% in the Post-Intervention survey but slightly decreased to 82.1% in the 30-day Follow Up survey.
- A total of 8.9% of participants in the Pre-Intervention survey indicated that they were independent in their ability to optimize vessel visualization by adjusting depth and gain. This percentage increased to 72.1% in the Post-Intervention survey but decreased to 61.5% in the 30-day Follow Up survey.
- A total of 8.9% of participants in the Pre-Intervention survey indicated that they were independent in their ability to optimize vessel visualization by utilizing the Doppler mode. This percentage increased to 60.5% in the Post-Intervention survey but significantly decreased to 41% in the 30-day Follow Up survey.

- A total of 2.2% of participants in the Pre-Intervention survey indicated that they were independent in their ability to measure depth of the vascular structures beneath the surface of the skin. This percentage increased to 62.8% in the Post-Intervention survey but slightly decreased to 59% in the 30-day Follow Up survey.
- A total of 6.7% of participants in the Pre-Intervention survey indicated that they were independent in their ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-plane) views. This percentage increased to 65.1% in the Post-Intervention survey but slightly decreased to 61.5% in the 30-day Follow Up survey.
- A total of 22.2% of participants in the Pre-Intervention survey indicated that they were independent in their ability to properly orient the probe on the patient to the US screen. This percentage increased to 81.4% in the Post-Intervention survey but decreased to 74.4% in the 30-day Follow Up survey.
- A total of 22.2% of participants in the Pre-Intervention survey indicated that they were independent in their ability to manipulate the US probe to ensure midline placement of target vessel (radial artery). This percentage increased to 74.4% in the Post-Intervention survey and further increased to 79.5% in the 30-day Follow Up survey.
- A total of 17.8% of participants in the Pre-Intervention survey indicated that they were independent in their ability to demonstrate proper hand technique to prevent loss of image from probe movement. This percentage increased to 76.7% in the Post-Intervention survey but decreased to 69.2% in the 30-day Follow Up survey.
- A total of 17.8% of participants in the Pre-Intervention survey indicated that they were independent in their ability to differentiate arteries from veins. This percentage increased

to 72.1% in the Post-Intervention survey and further increased to 79.5% in the 30-day Follow Up survey.

- A total of 4.4% of participants in the Pre-Intervention survey indicated that they were independent in their ability to enter patient demographics including name and clinic number. This percentage increased to 81.4% in the Post-Intervention survey but decreased to 71.8% in the 30-day Follow Up survey.
- A total of 4.4% of participants in the Pre-Intervention survey indicated that they were independent in their ability to record and save image. This percentage increased to 72.1% in the Post-Intervention survey but decreased to 71.8% in the 30-day Follow Up survey.

Planned, post hoc contrasts revealed that ability to perform eleven of the twelve US-related skills significantly increased between Pre-Intervention and Post-Intervention, between Pre-Intervention and 30-Day Follow-up, but not between Post-Intervention and 30-Day Follow-up. Lack of changes in the Post-Intervention and 30-Day Follow-up may be a result of clinicians' ability to perform skills acquired in the educational intervention leveling off or had not changed in the 30 days immediately following it. Planned post hoc contrasts confirmed that the ability to turn on the US machine did not change between Pre-Intervention and Post-Intervention, between Pre-Intervention and 30-Day Follow-up, or between Post-Intervention and 30-Day Follow-up. These results indicate the ability to turn on the US machine was optimal prior to the educational intervention. Ability to manipulate the US probe to ensure midline placement of target vessel and ability to differentiate arteries from veins continued to rise throughout all three survey intervals, suggesting utilization of US in the clinical setting following the educational intervention continued and abilities improved.

Findings Related to US Competence.

By May 1, 2018, at least 80% of Lead CRNAs who participate in the educational intervention will successfully cannulate an US trainer model's radial artery with US-guidance as evidenced by return of red liquid in the catheter, and indirect visualization of the catheter in the artery via US.

Statistical data retrieved from the Post-Intervention survey indicated that all Lead CRNAs who participated in the educational intervention were able to successfully cannulate the US trainer model's radial artery with US-guidance.

By May 1, 2018, perceived competency among Lead CRNAs who participate in the educational intervention will increase as evidenced by aggregate improvements in self-reported five-point Likert scale competency ratings from the Pre-Intervention to the Post-Intervention and Thirty-day Follow-up Surveys.

Overall perceived competency in the use of US to guide RAC was determined using a five-point Likert scale (not competent to highly competent) and evaluated at all three survey intervals. Planned post hoc contrasts confirmed that confidence significantly increased between Pre-Intervention and Post-Intervention, between Pre-Intervention and 30-Day Follow-up, but not between Post-Intervention and 30-Day Follow-up. This is noteworthy because it suggests that the use of US-guided RAC is a skill that requires continuing re-training. A total of 20% of the participants who completed the Pre-Intervention survey indicated that they were either "competent" or "highly competent" in the use of US to guide RAC. Following the educational intervention, 79.1% of participants who completed the Post-Intervention Survey indicated that they were either "competent" or "highly competent" in the use of US to guide RAC. This

percentage increased in the 30-Day Follow Up survey, with 84.6% of participants indicating that they were “competent” or “highly competent” in the use of US to guide RAC.

Findings Related to Level of Confidence.

By May 1, 2018, level of confidence in the use of US technology to guide RAC among Lead CRNAs who participate in the educational intervention will increase as evidenced by aggregate improvements in self-reported five-point Likert scale level of confidence ratings from the Pre-Intervention to the Post-Intervention and 30-day Follow-up Surveys.

Level-of-confidence in the use of US to guide RAC was determined using a five-point Likert scale (not at all confident to very confident) and was evaluated at all three survey intervals. Planned post hoc contrasts confirmed that confidence significantly increased between Pre-Intervention and Post-Intervention, between Pre-Intervention and 30-Day Follow-up, but not between Post-Intervention and 30-Day Follow-up. A total of 20% of the participants who completed the Pre-Intervention survey indicated that they were either “confident” or “very confident” in the use of US to guide RAC. Following the educational intervention, 86% of participants who completed the Post-Intervention Survey indicated that they were either “confident” or “very confident” in the use of US to guide RAC. This percentage slightly decreased in the 30-Day Follow Up survey, with 79.5% of participants indicating they were “confident” or “very confident” in the use of US to guide RAC.

Findings Related to US Utilization

By May 1, 2018, at least 50% of Lead CRNAs who participate in the educational intervention will indicate usage of US to guide RAC in their clinical practice as measured by participant response on the 30-day Follow-up survey to the question, “In the last 30 days, how many times have you utilized US to guide RAC in your clinical practice?”

Utilization of US to guide RAC in the clinical practice setting was determined by asking participants in the 30-Day Follow-Up survey to indicate the number of times that they utilized US in the thirty days since attending the US educational intervention. Of the thirty-nine participants, 59% indicated they had utilized US in the clinical setting at least once after the educational intervention. For seven out of thirty-nine participants (17.9%), the opportunity to utilize US to guide RAC did not present itself in this short period of time; five out of thirty-nine participants (12.8%) did not think of using US for RAC, and thus did not utilize the technology when performing the procedure.

Clinical Implications

Ultrasound guided techniques have become the standard of care for placement of central venous catheters. Current evidence strongly suggests that US guidance should be the standard of care for RAC (Lamperti et al., 2012). The results of this study directly influence how CRNAs practice. Familiarity with US technique will benefit operators whether the technique is used routinely, or as a rescue technique after initial palpation attempts fail. Healthcare institutions could use the findings from this project as a basis for developing an institutional program to establish US competency to improve patient safety. Multiple learning methodologies should be considered. Results from this study indicated that hands-on simulation was the most effective technique followed by didactic via PowerPoint. Furthermore, in healthcare institutions where CRNAs have access to US technology, this educational intervention can be implemented with minimal barriers to improving US knowledge, confidence, competence, and utilization.

Confidence using US technology significantly increased following the educational intervention. Clinicians are more likely to incorporate technology into their practice when they are confident using it (Lewiss, Hoffmann, Beaulieu, & Phelan, 2014). Healthcare institutions

that are interested in increasing CRNA confidence when using US, may consider implementing a similar educational intervention consisting of both didactic and hands on simulation. Data obtained from the Post-Intervention survey indicated that simulation utilizing the US model was an effective method of teaching participants how to use US to guide RAC. Of the participants who completed the Post-Intervention survey, 86% indicated that simulation was most conducive to their learning needs. This finding is consistent with the literature regarding the impact simulation education has on confidence levels and attitude performing procedures (Gasko et al., 2012).

Because US use to guide RAC is not specific to CRNAs only, other specialties that use this technology to cannulate the radial artery may benefit from similar training, as well. Interestingly, during the implementation of this project, this researcher was asked by the director of the Clinical Research Unit (CRU) if RNs from the CRU could attend one of the educational interventions. The standard practice of placing US-guided radial arterial lines in this unit by anesthesiologists was being delegated to the RNs who are responsible for placing the arterial lines. Following completion of the last educational intervention on February 19, 2018, the researcher presented a separate session for the CRU RNs, which is an example of an opportunity to expand the clinical intervention to outside the anesthesia practice arena.

Limitations

There were several limitations to this study. First, and potentially the most limiting, was the number of participants in this DNP project. The use of a small, convenience sample may have resulted in a lack of statistical power in the analysis of certain data, and the lack of randomization of the sample compromised the representativeness of this sample in relation to the population. Participants were restricted to those Lead CRNAs employed at specific health care

campuses; therefore, Lead CRNAs employed at the downtown campus and within the health system's community practice did not participate. This pilot study represents a small percentage of CRNAs within the institution and overall in the country; consequently, the sample was not a national representation of CRNA members, but the results obtained with the small sample may suggest an opportunity for program expansion, such as with the Clinical Research Unit (CRU). Of noteworthiness, Lead CRNAs are highly motivated and active individuals within the institution's anesthesia practice, and thus potentially may be more engaged learners.

Another limitation of this DNP project was related to data analysis. Data were collected and analyzed in aggregate format; therefore, paired-sample/repeated-measures correlations could not be calculated. Future research may benefit from pairing individual surveys to better understand the differences among practicing CRNAs. Finally, transferring the skills obtained from the educational intervention into the clinical setting takes due diligence, time, and practice. Due to time constraints of this DNP project, assessment of utilization in the clinical setting was limited to thirty days to ensure time for data collection and project completion. Institutions that implement a similar training program should consider a period of at least six months to reassess changes in clinical practice. An unforeseen limitation of this DNP project was a lack of equipment availability that emerged. This limitation played a significant part in the educational intervention and in clinical practice. Due to the anesthesia department's ability to provide only three US machines, class size was limited to six participants because to complete one-on-one mentoring of US vascular assessments, one machine was needed for every two participants. Following completion of the educational intervention, an increase in the use of US to guide RAC was observed. Due to the institution's high use of US for regional anesthesia, providers shared that they were often unable to locate US machines when they were needed. Although the

improved safety that is documented in the literature when US is used to guide RAC translates into financial savings for a healthcare institution, increased equipment acquisition costs may be required, due to increased US machine utilization.

Recommendations for Future Research

This project did not evaluate the cost of training, program implementation, or recurrent training. Future research analyses could be conducted by identifying cost-effective solutions and providing additional training; accordingly, such analysis may include both the availability and costs of training materials and personnel. Additionally, this project did not measure transferability between knowledge and skill acquired among learners in the classroom to success in the clinical practice setting. Future quantitative research should assess key clinical indicators of time to successful RAC and overall number of attempts to successful cannulation following implementation of an US educational intervention among CRNAs.

This project's population was limited to Lead CRNAs within one of the institution's three practice settings, which represented approximately 15% of the institutions CRNAs. Given that this DNP project was considered a pilot study, future studies could benefit from a larger sample size of CRNAs incorporating clinicians with various levels of expertise across the entire institution. Beyond the researcher's own institution, looking more broadly at CRNAs from across the United States would be beneficial which would not only yield more data, but would also would have the potential to sample different areas of the country to determine if regional differences in CRNA skill, confidence, and utilization rates of US existed.

Additionally, information from this DNP project could be used to guide future educational efforts and allocation of resources in the educational arena to advance the US skills of Student Registered Nurse Anesthetists (SRNAs). Receiving training in the use of US to guide

arterial cannulation, regardless of anatomical location, is not a requirement for SRNAs; unfortunately, this results in SRNAs entering practice with minimal to no experience for this skill set. Techniques utilized in this DNP project – both didactic and hands-on simulation – are readily available in a classroom setting. Integration of US education into the SRNA curriculum would allow students to become competent users of the technology through repeated exposure during clinicals. A pilot study including SRNAs might have the effect of prompting curriculum changes in nurse anesthesia programs throughout the country. The researcher is presently collaborating with the institution's Nurse Anesthesia Training program to integrate this DNP project into their one-day US education seminar, which at the current time does not teach US skills specific to RAC.

Sustainability

Following completion of this DNP project, results will be disseminated to the institution's team of CRNAs at a designated all-CRNA quarterly meeting. Furthermore, opening the educational intervention to all Lead and non-Lead CRNAs within the current facility and affiliated hospitals will be implemented. For those who were not able to participate in this study, the classroom presentation and video content have been archived on the Department of Anesthesia webpage. To facilitate the results of this project reaching a larger audience outside of this Midwestern academic center, results will be disseminated via poster presentation at the 44th Annual Mayo Clinic Seminar for Nurse Anesthesia.

Conclusion

The purpose of this DNP scholarly project was to develop and implement an educational intervention for the use of US to guide RAC among Lead CRNAs in a large, Midwestern academic center. Statistically significant improvements in US knowledge, US competency, and

level of confidence in the use of US technology were achieved because of this DNP project. Furthermore, clinical utilization of US technology to guide RAC also improved.

To date, there are no CRNA studies reporting on any formal RAC training programs. Based on the successful outcomes achieved and the positive feedback from the participants in this DNP project, similar training programs can be conducted within anesthesia departments at other institutions who want to initiate and improve cannulation programs. ultra

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Appendix A

Knowles Conditions of Learning

- The learners feel a need to learn.
- Physical comfort, mutual trust and respect, mutual helpfulness, freedom of expression, and acceptance of differences characterize the learning environment.
- The learners perceive the goals of a learning experience to be their goals.
- The learners accept a share of the responsibility for planning and operating a learning experience, and therefore have a feeling of commitment toward it.
- The learners participate actively in the learning process.
- The learning process is related to and makes use of the experience of the learners.
- The learners have a sense of progress toward their goals.

Knowles Principles of Teaching

- The teacher exposes the learners to new possibilities for self-fulfillment.
- The teacher helps the learners clarify their own aspirations for improved behavior.
- The teacher helps the learners diagnose the gap between their aspirations and their present level of performance.
- The teacher provides physical conditions that are comfortable (as to seating, smoking, temperature, ventilation, lighting, and decoration) and conducive to interaction (preferably, no person sitting behind another person).
- The teacher accepts the learners as persons of worth and respects their feelings and ideas.

- The teacher seeks to build relationships of mutual trust and helpfulness among the learners by encouraging cooperative activities and refraining from inducing competitiveness and judgmentalness.
- The teacher exposes his or her own feelings and contributes resources as a co-learner in the spirit of mutual inquiry.
- The teacher involves the learners in a mutual process of formulating learning objectives in which the needs of the learners of the institution, of the teacher, of the subject matter, and of the society are considered.
- The teacher shares his or her thinking about options available in the designing of learning experiences and the selection of materials and methods and involves the learner's in deciding among these options jointly.
- The teacher helps the learners to organize the learning process themselves (project groups, learning-teaching teams, independent study, etc.) to share responsibility in the process of mutual inquiry.
- The teacher helps the learners exploit their own experiences as resources for learning using such techniques as discussion, role-playing, case method, etc.
- The teacher gears the presentation of his or her own resources to the levels of experience of learners.
- The teacher helps the learners to apply new learning to their experience, and thus to make the learning's more meaningful and integrated.
- The teacher involves the learners in developing mutually acceptable criteria and methods for measuring progress toward the learning objectives.
- The teacher helps the learners develop and apply procedures for self-evaluation.

Appendix B

AHRQ Recommended Training Objectives for Ultrasound-Guided Vascular Cannulation

Cognitive Skills

1. Knowledge of the physical principles of ultrasound.
2. Knowledge of the operation of the ultrasound equipment, including the controls that affect the imaging display.
3. Knowledge of infection control standards for performing vascular access and sterile preparation of the ultrasound probe for real-time use.
4. Knowledge of the surface anatomy specific to the access site and ultrasound anatomy that allows identification of the target vessel and structures that are to be avoided.
5. Ability to recognize the location and patency of the target vessel.
6. Ability to recognize atypical anatomy of vessel location and redirect the needle entry to minimize complications.
7. Knowledge of the color flow and spectral Doppler flow patterns that identify arterial and venous flow characteristics.

Technical Skills

1. Ability to operate the ultrasound equipment and controls to produce quality information to identify the target vessel.
2. Dexterity to coordinate needle guidance in the desired direction and depth based on the imaging data.
3. Use of needle guides for coordination of needle insertion with imaging data when operator dexterity is lacking, or clinical conditions make dexterity coordination challenging.

4. Ability to insert the catheter into the target vessel using ultrasound information.
5. Ability to confirm catheter placement into the target vessel and the absence of the catheter in unintended vessels and structure

Appendix C

US-Related Concepts

1. Understanding of how US transmits sound waves into a resultant image
2. Understanding of how penetration affects US images
3. Understanding of how resolution affects US images
4. Understanding of how echogenicity affects US images

US-Related Skills

1. Ability to turn on the US machine
2. Ability to select appropriate US probe
3. Ability to optimize vessel visualization by adjusting depth and gain
4. Ability to measure depth of vascular structures beneath the surface of the skin
5. Ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-plane) views
6. Ability to properly orient the probe on the patient to the US screen
7. Ability to manipulate the US probe to ensure midline placement of target vessel (radial artery)
8. Ability to demonstrate proper hand technique to prevent loss of image from probe movement
9. Ability to differentiate arteries from veins
10. Ability to enter patient demographics including name and clinic number
11. Ability to record and save image
12. Ability to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for US-guided RAC

Appendix D

Project Timeline

Educational Intervention

Date	Time	Location	Participants
01/15/2018	7:00-8:00 A.M.	MB 2-716	4
01/15/2018	10:00-11:00 A.M.	MB 2-716	4
01/22/2018	10:00-11:00 A.M.	MB 2-716	5
01/29/2018	7:00-8:00 A.M.	MB 2-716	5
01/29/2018	10:00-11:00 A.M.	MB 2-716	7
02/02/2018	10:00-11:00 A.M.	MB 2-716	5
02/07/2018	10:00-11:00 A.M.	MB 2-716	6
02/09/2018	10:00-11:00 A.M.	MB 2-716	5
02/19/2018	10:00-11:00 A.M.	MB 2-710	6

Surveys

Name	Release Date	Deadline
Needs Assessment Survey & Pre-Intervention Survey	12/05/2017	12/29/2017
Post-Intervention Survey	01/15/2017	01/29/2018
Post-Intervention Survey	01/22/2017	02/05/2018
Post-Intervention Survey	01/29/2018	02/12/2018
Post-Intervention Survey	02/02/2018	02/16/2018
Post-Intervention Survey	02/07/2019	02/21/2018
Post-Intervention Survey	02/09/2018	02/23/2018
Post-Intervention Survey	02/19/2018	03/05/2018
30-Day Follow-Up Survey	02/15/2018	03/01/2018
30-Day Follow-Up Survey	02/22/2018	03/08/2018
30-Day Follow-Up Survey	02/28/2018	03/14/2018
30-Day Follow-Up Survey	03/02/2018	03/16/2018
30-Day Follow-Up Survey	03/07/2018	03/21/2018
30-Day Follow-Up Survey	03/09/2018	03/23/2018
30-Day Follow-Up Survey	03/19/2018	04/02/2018

Appendix E

Data Collection Surveys

Needs Assessment Survey

Page 1 of 6

Please complete the survey below.

Thank you!

- 1) How many times per month do you encounter patients that present with difficult arterial access?
 - ☐ 1
 - ☐ 2
 - ☐ 3
 - ☐ 4
 - ☐ 5
 - ☐ More than 5
- 2) In the last 6 months, how many failed arterial attempts do you usually reach prior to asking for assistance for a given patient?
 - ☐ 1
 - ☐ 2
 - ☐ 3
 - ☐ 4
 - ☐ 5
 - ☐ More than 5 or I don't ask for assistance
- 3) In the last 6 months, how many times have you utilized ultrasound to guide radial arterial cannulation?
 - ☐ Never
 - ☐ 1
 - ☐ 2
 - ☐ 3
 - ☐ 4
 - ☐ 5
 - ☐ More than 5
- 4) Have you ever received education (formal or informal) on ultrasound imaging after your formal anesthesia education?
 - ☐ Yes
 - ☐ No
- 5) Please select the type(s) of education you received. (check all that apply)
 - ☐ Workshop/conference
 - ☐ Computer-based (self-guided)
 - ☐ Internet (YouTube, etc.)
 - ☐ Employer provided training (in-services)
 - ☐ Trial and error
 - ☐ Clinical-based training by a colleague
 - ☐ Textbook

Please indicate your level of agreement with the following statements.

- | | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|-----------------------|-----------------------|----------------------------|-----------------------|-----------------------|
| 6) Being proficient in the use of ultrasound to guide radial arterial cannulation will enhance the CRNA practice in my institution. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7) I have the training and experience needed to perform ultrasound-guided radial arterial cannulation independently.

☐☐☐☐☐

8) Please indicate your level of interest in receiving formal ultrasound education and hands on training for radial arterial cannulation.

☐ Very interested

☐ Somewhat interested

☐ Neutral

☐ Not very interested

☐ Not at all interested

Pre-Intervention Survey

Please complete the survey below.

Thank you!

- 9) Please indicate your gender.
- ☐ Male
☐ Female
- 10) Please indicate your age.
- ☐ 25-34
☐ 35-44
☐ 45-54
☐ 55 and over
☐ I prefer not to say
- 11) Please indicate your highest level of education.
- ☐ Certificate
☐ Bachelors Degree
☐ Master's Degree
☐ Doctoral Degree
- 12) Where did you complete your nurse anesthesia education?
- ☐ Mayo Clinic Nurse Anesthesia Program
☐ Other
- 13) Please provide the name of other institution where you received your nurse anesthesia program.
- _____
- 14) How many years have you been practicing as a CRNA?
- ☐ Less than 5
☐ 5-10
☐ 11-15
☐ 16-20
☐ More than 20
- 15) In which division(s) are you currently a lead CRNA? (select all that apply)
- ☐ Cardiac
☐ Neuro
☐ Central
☐ Multi 1
☐ Multi 2 (Peds)
☐ Vascular Lab
☐ Cardiac Catheter Lab
☐ GI
- 16) How many years have you been a lead CRNA?
- ☐ Less than 5
☐ 5-10
☐ 11-15
☐ 16-20
☐ More than 20

Please rate your understanding of the following ultrasound related concepts.

- | | Do not understand | Understand a little | Understand most of it | Understand very well |
|---|-----------------------|-----------------------|-----------------------|-----------------------|
| 17) Understanding of how ultrasound transmits sound waves into a resultant image. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 18) Understanding of how penetration affects ultrasound images. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 19) Understanding of how resolution affects ultrasound images. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 20) Understanding of how echogenicity affects ultrasound images. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Please rate your abilities in the following ultrasound related skills

	Dependent - Fully dependent on assistance to execute this task	Need Assistance - Limited understanding, require frequent directive cues	Need Supervision - Confident in ability, but need occasional knowledge prompting or supportive cues	Independent - Confident, proficient, do not need supportive cues
21) Ability to turn on the ultrasound machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22) Ability to select appropriate ultrasound probe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23) Ability to optimize vessel visualization by adjusting depth and gain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24) Ability to optimize vessel visualization by utilizing the Doppler mode	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25) Ability to measure depth of vascular structures beneath the surface of the skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26) Ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-plane) views.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27) Ability to properly orient the probe on the patient to the ultrasound screen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28) Ability to manipulate ultrasound probe to ensure midline placement of target vessel (radial artery)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
29) Ability to demonstrate proper hand technique to prevent loss of image from probe movement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
30) Ability to differentiate arteries from veins	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
31) Ability to enter patient demographics including name and clinic number	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
32) Ability to record and save image	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33) Are you able to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for ultrasound-guided radial arterial cannulation?		<input type="radio"/> Yes <input type="radio"/> No		

- 34) How would you describe your level of confidence in the use of ultrasound to guide radial arterial cannulation?
- ☐ Very confident
 - ☐ Confident
 - ☐ Neutral
 - ☐ Not very confident
 - ☐ Not at all confident
- 35) How would you rate your perceived competency overall in the use of ultrasound to guide radial arterial cannulation?
- ☐ Highly competent
 - ☐ Competent
 - ☐ Uncertain
 - ☐ Somewhat competent
 - ☐ Not competent

Post-Intervention Survey

Please complete the survey below.

Thank you!

Please rate your understanding of the following ultrasound related concepts.

	Do not understand	Understand a little	Understand most of it	Understand very well
1) Understanding of how ultrasound transmits sound waves into a resultant image.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2) Understanding of how penetration affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3) Understanding of how resolution affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4) Understanding of how echogenicity affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please rate your abilities in the following ultrasound related skills

	Dependent - Fully dependent on assistance to execute this task	Need Assistance - Limited understanding, require frequent directive cues	Need Supervision - Confident in ability, but need occasional knowledge prompting or supportive cues	Independent - Confident, proficient, do not need supportive cues
5) Ability to turn on the ultrasound machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6) Ability to select appropriate ultrasound probe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7) Ability to optimize vessel visualization by adjusting depth and gain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8) Ability to optimize vessel visualization by utilizing the Doppler mode	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9) Ability to measure depth of vascular structures beneath the surface of the skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- 10) Ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-plane) views. ☐ ☐ ☐ ☐
- 11) Ability to properly orient the probe on the patient to the ultrasound screen ☐ ☐ ☐ ☐
- 12) Ability to manipulate ultrasound probe to ensure midline placement of target vessel (radial artery) ☐ ☐ ☐ ☐
- 13) Ability to demonstrate proper hand technique to prevent loss of image from probe movement ☐ ☐ ☐ ☐
- 14) Ability to differentiate arteries from veins ☐ ☐ ☐ ☐
- 15) Ability to enter patient demographics including name and clinic number ☐ ☐ ☐ ☐
- 16) Ability to record and save image ☐ ☐ ☐ ☐
- 17) Are you able to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for ultrasound-guided radial arterial cannulation? ☐ Yes
☐ No
- 18) How would you describe your level of confidence in the use of ultrasound to guide radial arterial cannulation as a result of the educational intervention? ☐ Very confident
☐ Confident
☐ Neutral
☐ Not very confident
☐ Not at all confident
- 19) How would you rate your perceived competency overall in the use of ultrasound to guide radial arterial cannulation as a result of the educational intervention? ☐ Highly competent
☐ Competent
☐ Uncertain
☐ Somewhat competent
☐ Not competent
- 20) How likely are you to utilize ultrasound technology to guide radial arterial cannulation in your practice as a result of the educational intervention? ☐ Extremely likely
☐ Likely
☐ Neutral
☐ Unlikely
☐ Extremely unlikely
- 21) Were you able to successfully cannulate the model's radial artery with the guidance of ultrasound, as evidenced by return of red liquid in the catheter and indirect visualization of the catheter in the artery via ultrasound? ☐ Yes
☐ No
- 22) Which portion of the educational intervention was most conducive to your learning needs? ☐ Video
☐ Power Point Presentation
☐ Simulation with ultrasound model

23) Additional comments:

30-Day Follow-up Survey

Please complete the survey below.

Thank you!

Please rate your understanding of the following ultrasound related concepts.

	Do not understand	Understand a little	Understand most of it	Understand very well
1) Understanding of how ultrasound transmits sound waves into a resultant image.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2) Understanding of how penetration affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3) Understanding of how resolution affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4) Understanding of how echogenicity affects ultrasound images.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please rate your abilities in the following ultrasound related skills

	Dependent - Fully dependent on assistance to execute this task	Need Assistance - Limited understanding, require frequent directive cues	Need Supervision - Confident in ability, but need occasional knowledge prompting or supportive cues	Independent - Confident, proficient, do not need supportive cues
5) Ability to turn on the ultrasound machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6) Ability to select appropriate ultrasound probe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7) Ability to optimize vessel visualization by adjusting depth and gain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8) Ability to optimize vessel visualization by utilizing the Doppler mode	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9) Ability to measure depth of vascular structures beneath the surface of the skin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- | | | | | |
|--|--|-----------------------|-----------------------|-----------------------|
| 10) Ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-plane) views. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 11) Ability to properly orient the probe on the patient to the ultrasound screen | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 12) Ability to manipulate ultrasound probe to ensure midline placement of target vessel (radial artery) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 13) Ability to demonstrate proper technique to prevent loss of image from probe movement | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 14) Ability to differentiate arteries from veins | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 15) Ability to enter patient demographics including name and clinic number | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 16) Ability to record and save image | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 17) Are you able to verbalize the Centers for Disease Control and Prevention's recommended barrier precautions related to sterile technique for ultrasound-guided radial arterial cannulation? | <input type="radio"/> Yes
<input type="radio"/> No | | | |
| 18) How would you describe your level of confidence in the use of ultrasound to guide radial arterial cannulation as a result of the educational intervention? | <input type="radio"/> Very confident
<input type="radio"/> Confident
<input type="radio"/> Neutral
<input type="radio"/> Not very confident
<input type="radio"/> Not at all confident | | | |
| 19) How would you rate your perceived competency overall in the use of ultrasound to guide radial arterial cannulation as a result of the educational intervention? | <input type="radio"/> Highly competent
<input type="radio"/> Competent
<input type="radio"/> Uncertain
<input type="radio"/> Somewhat competent
<input type="radio"/> Not competent | | | |

- | | |
|--|---|
| 20) In the last 30 days, how many times have you utilized ultrasound to guide radial arterial cannulation in your clinical practice? | <input type="radio"/> Never
<input type="radio"/> 1
<input type="radio"/> 2
<input type="radio"/> 3
<input type="radio"/> 4
<input type="radio"/> 5
<input type="radio"/> More than 5 |
|--|---|

21) Please indicate the reason you did not utilize ultrasound to guide radial arterial cannulation.

- ☐ I did not care for a patient requiring radial arterial access
- ☐ I did not think of using ultrasound for radial arterial access
- ☐ I am not interested in using ultrasound for radial arterial access
- ☐ I am not comfortable using ultrasound for radial arterial access

Additional comments:

Appendix F

Knowledge of US-related concepts

1. Understanding of how ultrasound transmits sound waves into a resultant image

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.36	3.42	3.15
<i>SD</i>	0.830	0.698	0.670
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.108

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 24.625$, $p = .000$, $\eta^2 = 0.284$

2. Understanding of how penetration affects ultrasound images

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.29	3.42	3.15
<i>SD</i>	0.757	0.698	0.670
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.095

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 30.325$, $p = .000$, $\eta^2 = 0.328$

3. Understanding of how resolution affects ultrasound images

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.20	3.37	3.15
<i>SD</i>	0.632	0.655	0.670
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.133

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 39.260$, $p = .000$, $\eta^2 = 0.390$

4. Understanding of how echogenicity affects ultrasound images

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.20	3.37	3.15
<i>SD</i>	0.632	0.655	0.670
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.110

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 65.627$, $p = .000$, $\eta^2 = 0.365$

Knowledge of US-related skills

1. Ability to turn on the ultrasound machine

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	3.58	3.37	3.15
<i>SD</i>	0.839	0.655	0.670
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.074	.236	.576

analysis of variance indicates that significant differences do not exist between the three survey periods, $F(2,124) = 1.696$, $p = .188$, $\eta^2 = 0.027$

2. Ability to select appropriate ultrasound probe

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.93	3.77	3.72
<i>SD</i>	0.837	0.684	0.724
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.767

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 16.863$, $p = .000$, $\eta^2 = 0.214$

3. Ability to optimize vessel visualization by adjusting depth and gain

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.48	3.63	3.49
<i>SD</i>	0.762	0.691	0.721
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.392

the analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 32.317$, $p = .000$, $\eta^2 = 0.344$

4. Ability to optimize vessel visualization by utilizing the Doppler mode

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.22	3.51	3.34
<i>SD</i>	0.795	0.736	0.627
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.297

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 40.567$, $p = .000$, $\eta^2 = 0.397$

5. Ability to measure depth of vascular structures beneath the surface of the skin

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.09	3.55	3.49
<i>SD</i>	0.763	0.705	0.683
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.707

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 57.072$, $p = .000$, $\eta^2 = 0.481$

6. Ability to image the radial artery in both the short-axis (out-of-plane) and long-axis (in-place) views

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.24	3.56	3.51
<i>SD</i>	0.773	0.700	0.721
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.780

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 45.159$, $p = .000$, $\eta^2 = 0.421$

7. Ability to properly orient the probe on the patient to the ultrasound screen

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.73	3.74	3.62
<i>SD</i>	0.915	0.621	0.782
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.459

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 21.589$, $p = .000$, $\eta^2 = 0.258$

8. Ability to manipulate ultrasound probe to ensure midline placement of target vessel

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.69	3.65	3.69
<i>SD</i>	0.949	0.720	0.731
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.819

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 21.277$, $p = .000$, $\eta^2 = 0.255$

9. Ability to demonstrate proper hand technique to prevent loss of image from probe movement

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.62	3.67	3.59
<i>SD</i>	0.886	0.754	0.751
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.667

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 22.848$, $p = .000$, $\eta^2 = 0.271$

10. Ability to differentiate arteries from veins

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.93	3.63	3.69
<i>SD</i>	0.688	0.725	0.694
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.679

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 15.578$, $p = .000$, $\eta^2 = 0.201$

11. Ability to enter patient demographics, including name and clinic number

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	1.96	3.72	3.59
<i>SD</i>	0.796	0.701	0.785
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.438

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 72.856$, $p = .000$, $\eta^2 = 0.540$

12. Ability to record and save images

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	1.93	3.63	3.62
<i>SD</i>	0.818	0.726	0.747
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.941

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 69.801$, $p = .000$, $\eta^2 = 0.531$

Level of Confidence

How would you describe your level of confidence in the use of ultrasound to guide RAC

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.49	4.23	4.00
<i>SD</i>	1.014	0.684	0.649
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.195

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,124) = 60.218$, $p = .000$, $\eta^2 = 0.493$

Perceived Competency

	Pre-Intervention	Post-Intervention	30-Day Follow-up
<i>M</i>	2.33	3.97	3.83
<i>SD</i>	1.087	0.537	0.935
	Pre to Post	Pre to 30-day	Post to 30-day
<i>p</i>	.000	.000	.481

analysis of variance indicates that significant differences exist between two pairs of the three survey periods, $F(2,123) = 44.514$, $p = .000$, $\eta^2 = 0.420$

Appendix G

Staff Consent Cover Letter

My name is Brandee Kroening and I am a DNP student at the University of North Dakota. You are invited to participate in a research study regarding ultrasound utilization to guide radial arterial cannulation as you are a Lead Certified Registered Nurse Anesthetist. The purpose of this DNP scholarly project is to develop and implement an educational program for the use of ultrasound to guide radial arterial line placement among Lead Certified Registered Nurse Anesthetists. The overall goal of this project is to improve the utilization of ultrasound technology to guide radial arterial cannulation among Lead Certified Registered Nurse Anesthetists.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 50 Lead Certified Registered Nurse Anesthetists will participate in this study at St. Mary's Hospital at the Mayo Clinic, Rochester, Minnesota.

HOW LONG WILL I BE IN THIS STUDY?

Your participation in the study will last 3 months.

WHAT WILL HAPPEN DURING THIS STUDY?

Prior to attending the educational program, two computer based surveys will be e-mailed to every Lead Certified Registered Nurse Anesthetists at St. Mary's hospital. In these surveys, you will be asked to complete an 8-item Needs Assessment survey related to ultrasound utilization to guide radial artery cannulation in your clinical practice. You will also be asked to complete a 27-item Pre-Intervention survey. Questions in this second survey are related to your educational preparation, years of experience, understanding of ultrasound, self-evaluation of your ability to perform ultrasound-related skills along with your level of confidence and perceived level of competency in the use of ultrasound technology to guide radial arterial cannulation. **Completion of these two surveys will serve as your informed consent to participate in this DNP Project.** Upon completion of the 2 surveys, you will be asked to participate in a 60-minute educational program presented during a designated Certified Registered Nurse Anesthesia meeting. This educational program includes a lecture presentation, video viewing and hands on practice with ultrasound machines and an arm mannequin. Immediately following the educational program and at 30 days following your participation in the educational program, you will be sent two surveys via email related to your understanding of ultrasound-related concepts, your self-reported ability to perform ultrasound-related skills along with your self-reported level of confidence and perceived competency in the use of ultrasound to guide radial arterial cannulation as a result of the educational program. Each survey should take less than 5 minutes to complete via REDCap secure web application. You are free to skip any questions that you prefer not to answer. There are no threats or repercussions to your employment, should you choose not to participate in this project or complete the surveys. There are also no repercussions to your

employment should your self-reporting indicate a lack of confidence in performing the ultrasound procedure.

WHAT ARE THE RISKS OF THE STUDY?

The Institutional Review Board of Mayo Clinic has approved this study and there are no foreseeable risks associated with project participation or refusal to participate in the DNP Project.

WHAT ARE THE BENEFITS OF THIS STUDY?

The benefit of participating in this study is the opportunity to receive individual focused learning on ultrasound concepts and skills. Furthermore, information collected from this study will add to the body of knowledge regarding the effectiveness of an ultrasound educational program for practicing Certified Registered Nurse Anesthetists' knowledge, competency and level of confidence with ultrasound technology.

IS THIS STUDY VOLUNTARY?

Your participation in this study is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota. Additionally, your decision to participate along with your responses will not affect your current employment status with Mayo Clinic.

ALTERNATIVES TO PARTICIPATING IN THIS STUDY

If you choose not to participate in this study, you may anonymously view the classroom presentation and video content on the Department of Anesthesia webpage where it will be archived.

CONFIDENTIALITY

All data obtained from this study will be de-identified and reported in aggregate format. Confidentiality will be maintained by means of collecting aggregate data via REDCap secure web application. The records of this study will be kept private to the extent permitted by law. Any reports or presentations related to this study that might be published will be de-identified. Your study record may be reviewed by Government agencies and the University of North Dakota Institutional Review Board.

If you have any questions concerning the survey or this research project in general, please contact the principal investigator, Brandee Kroening (kroening.brandee@mayo.edu) or the project advisor, Dr. Joanna Sikkema (joanna.sikkema@und.edu). If you later have questions, concerns, or complaints about the research please contact Brandee Kroening at 507-261-9382.